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OPEN RESONATORS, FORMED BY PARALLEL DISKS WITH ARBITRARY RATIO OF THEIR DIAMETER TO THE DISTANCE BETWEEN THEM

By

A. T. Fialkovskiy

FOREIGN TECHNOLOGY DIVISION

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А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
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И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
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К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
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М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

2239

OPEN RESONATORS, FORMED BY PARALLEL DISKS WITH ARBITRARY RATIO OF THEIR DIAMETER TO THE DISTANCE BETWEEN THEM.

A. T. Fialkovskiy.

Article was submitted 6 Oct. 1965.

The theory of good quality natural oscillations in an open resonator, formed by parallel round disks, is developed. In this case on the ratio of a/l (2a - diameter of disks, 2i - distance between them) are not placed any limitations, in particular, the distance between disks can be approximately equal to the half-wave or wave. The natural frequencies of high-quality oscillations are found. The problem is solved about the excitation of oscillations in the resonator by a plane wave, falling normally on the disk (with low transparency of disks).

Introduction

In [1] are examined resonators, consisting of two disks arranged one against the other (Fig. 1), under conditions $l \gg a$, $ka \gg 1$, where $k = \omega/c$ - wave number.

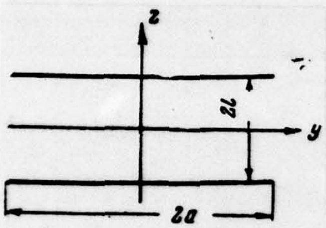

Fig. 1. Open resonator, formed by disks.

With $kl \sim 1$ (or $l \leqslant a$) the theory of disk resenators developed in [1] needs some refinement with respect to the following considerations. If wave H_{rq} or E_{rq} arrives at the open end of the flat waveguide at frequency close to its critical, then with $q \gg 1$ the coefficient of reflection is determined by formula [2]

$$R = -e^{i\beta(1+i)s}, \ \beta = 0.824. \qquad (1)$$

It does not depend on the wave polarization - the same for waves H_{oq} and E_{oq} - and pertains to the component of the field, directed along the coordinate axis, which the field does not depend on.

With arbitrary values q(q=1, 2, ...), i.e., when between plates are placed approximately half-waves, waves etc., the reflection factors are different for waves E_{0q} and H_{0q} and are determined by formulas

$$R_E = -e^{i(\beta' + i\beta''_E)s}, \quad R_H = -e^{i(\beta' + i\beta''_H)s}, \tag{2}$$

where $\beta', \beta''_E, \beta''_H$ depend on subscript q. They can be easily found from the strict theory of diffraction on the end of the waveguide (see Appendix), there values are presented in Fig. 2.

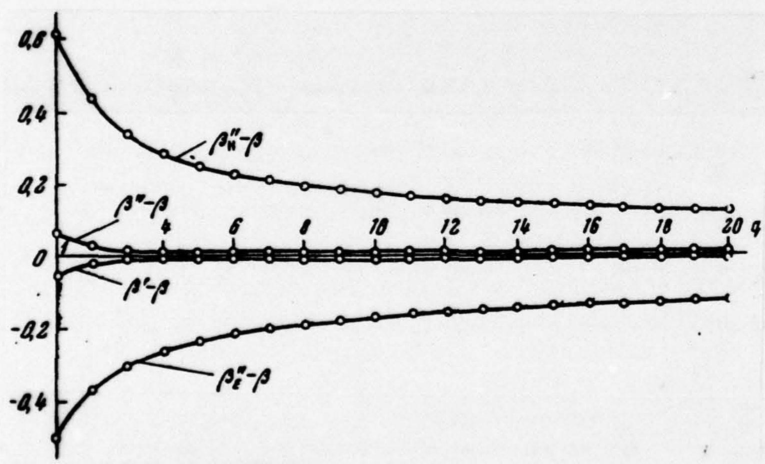

Fig. 2. Dependence of β', β''_E and β''_H on the number of halfwaves, placed between plates.

From Fig. 2 we see that the tendency of $\beta', \beta_E^{\bullet}$ and $\beta_H^{\bullet}$ to value β = 0.824 occurs quite slowly; since we will see below taking into account the difference of $\beta_E^{\bullet}$ from $\beta_H^{\bullet}$ the construction of the theory is substantially complicated.

§ 1. ANALYSIS OF NATURAL OSCILLATIONS

In cylindrical coordinate system r, ϕ, z let us use electric and magnetic Hertz vector [3]

$$\left.\begin{aligned}\Pi_z^e &= \frac{2}{kw} A J_m(wr) \frac{\cos}{\sin} v_q z \cos(m\varphi + \varphi_0),\\ \Pi_z^m &= \frac{2i}{kw} B J_m(wr) \frac{\sin}{\cos} v_q z \sin(m\varphi + \varphi_0),\end{aligned}\right\} \quad (3)$$

where A and B - arbitrary constants of multiplier, $w = \sqrt{k^2 - v_q^2}$ - radial wave number.

Then, substituting (3) in the Maxwell equation, with accuracy up to the rejected terms on the order of w^2/k^2 we obtain the expressions for electromagnetic field in our resonator

$$\left.\begin{aligned}
&E_\varphi = f_E(r)\,{}^{\sin}_{\cos}\,v_q z \sin(m\varphi+\varphi_0),\quad H_\varphi = i f_H(r)\,{}^{\cos}_{-\sin}\,v_q z\cos(m\varphi+\varphi_0),\\
&E_r = -f_H(r)\,{}^{\sin}_{\cos}\,v_q z\cos(m\varphi+\varphi_0),\quad H_r = i f_E(r)\,{}^{\cos}_{-\sin}\,v_q z\sin(m\varphi+\varphi_0),\\
&E_z = \frac{2w}{k} A J_m(wr)\,{}^{\cos}_{-\sin}\,v_q z\cos(m\varphi+\varphi_0),\\
&\qquad H_z = i\frac{2w}{k} B J_m(wr)\,{}^{\sin}_{\cos}\,v_q z\sin(m\varphi+\varphi_0),
\end{aligned}\right\} \quad (4)$$

where

$$\left.\begin{aligned}
&f_E(r) = CJ_{m-1}(wr) + DJ_{m+1}(wr),\\
&f_H(r) = CJ_{m-1}(wr) - DJ_{m+1}(wr),\\
&C = A + B,\ D = A - B,\ v_q = \frac{\pi q}{2l},\ q = 1, 2, \ldots
\end{aligned}\right\} \quad (5)$$

For determination of ratio D/C, radial wave number w and the frequency of oscillations $\omega = ck$ we use the reflection factor from the open end of the flat waveguide under the condition that the frequency of the wave is close to critical, and we put together the impedance boundary conditions on the edge (r = a) of our resonator

$$\left.\begin{aligned}
&f_E + \frac{y_E}{w}\frac{df_E}{dr} = 0,\\
&f_H + \frac{y_H}{w}\frac{df_H}{dr} = 0,
\end{aligned}\right\} \quad (6)$$

where, considering the smallness of the parameter

$$s = \sqrt{\frac{2l}{k}}\,w = \sqrt{4\pi p}\quad (2kl = \pi q + 2\pi p), \quad (7)$$

it is possible to assume

$$y_E = \frac{\beta' + i\beta''_E}{2}s;\quad y_H = \frac{\beta' + i\beta''_H}{2}s. \quad (8)$$

Substituting (5) in (6), we obtain

$$\left.\begin{aligned}[J_{m-1}(wa)+y_H J'_{m-1}(wa)]\,C+[J_{m+1}(wa)+y_H J'_{m+1}(wa)]\,D=0,\\ [J_{m-1}(wa)+y_E J'_{m-1}(wa)]\,C-[J_{m+1}(wa)+y_E J'_{m+1}(wa)]\,D=0.\end{aligned}\right\}\quad(9)$$

By equating the determinant of system (9) to zero, we obtain the characteristic equation

$$F_{m-1}F_{m+1}+\frac{y_E+y_H}{2}(F_{m-1}+F_{m+1})+y_E y_H=0, \qquad (10)$$

where

$$F_m=\frac{J_m(wa)}{J'_m(wa)}.$$

At small values of y_E, y_H in the first approximation the solutions of equation (10) have the form

$$s=\frac{2\nu_{m-1.n}}{M+\beta'+i\beta''} \text{ or } s=\frac{2\nu_{m+1.n}}{M+\beta'+i\beta''}\ (m=1,\ 2,\ \ldots), \qquad (11)$$

where

$$M=\sqrt{\frac{2k}{l}}\,a,\quad \beta''=\frac{\beta''_E+\beta''_H}{2}, \qquad (12)$$

and $\nu_{m,n}$ - n-th zero of function $J_m(x)$. By substituting (11) into one of equations (9), we determine the ratio D/C. When we take $\nu_{m+1,n}$, then

$$C/D=i\frac{wa}{2m}\frac{\beta''_E-\beta''_H}{4}s, \qquad (13)$$

and when $\nu_{m-1,n}$, then

$$D/C=-i\frac{wa}{2m}\frac{\beta''_E-\beta''_H}{4}s. \qquad (14)$$

With m = 0 equation (10) is broken down into two equalities:

$$F_{-1}=F_1=-y_E \text{ and } F_{-1}=F_1=-y_H, \tag{15}$$

where we obtain different natural frequencies, and so that equality (8) would be fulfilled, it is necessary to assume

$$C=D \text{ and } C=-D,$$

i.e., we come to the case investigated in [4], when it is possible to use only the magnetic or only the electric Hertz vector.

§ 2. CLASSIFICATION AND MAIN PROPERTIES OF NATURAL OSCILLATIONS

The oscillations being examined are characterized by three subscripts: m, n, q and still by Bessel function (J_{m-1} or J_{m+1}), the roots of which determine the natural frequencies and which in the first approximation determine the field of natural oscillation. Hence appears the natural formation of natural oscillations with the aid of four subscripts: $m(m-1)nq$; $m(m+1)nq$. Let us examine the main properties of oscillations in the given resonator.

1. Symmetrical oscillations (m = 0) appear from classification. According to [4], we will designate them through $E^{(\varphi)}_{0nq}$ and $H^{(\varphi)}_{0nq}$. The natural frequencies of these oscillations are determined by formulas

$$s=\frac{2\nu_{1,n}}{M+\beta'+i\beta''_E} \quad \overset{\text{or}}{\text{или}} \quad s=\frac{2\nu_{1,n}}{M+\beta'+i\beta''_H}. \qquad (16)$$

The difference of β''_E from β''_H leads to polarized decomposition of natural frequencies. Within the accuracy of formula (16) it is possible to only confirm that the imaginary parts of natural frequencies are distinguished by a value, proportional to $\beta''_E-\beta''_H$; for real parts a more precise investigation is necessary.

Unsymmetrical oscillations (m = 1, 2, 3, ...) correspond to classification. In this case the complex frequencies of natural oscillations m-1(m)nq and m+1(m)nq within the accuracy of formulas (11) coincide (however, with more precise solution of equation (10) the frequencies can be obtained slightly different). The natural frequency of oscillation 1(0)nq is a single nondegenerate frequency [within the accuracy of formulas (11)].

On the line, connecting in complex plane the natural frequencies of oscillations $E^{(\varphi)}_{0nq}$ and $H^{(\varphi)}_{0nq}$, at an equal distance from these

frequencies is placed the natural frequency of oscillation 2(1)nq.

Fig. 3 schematically shows the course of lines of force of electric (solid lines) and magnetic (broken) fields for oscillations 1(0)1q, 1(2)1q and 2(1)1q.

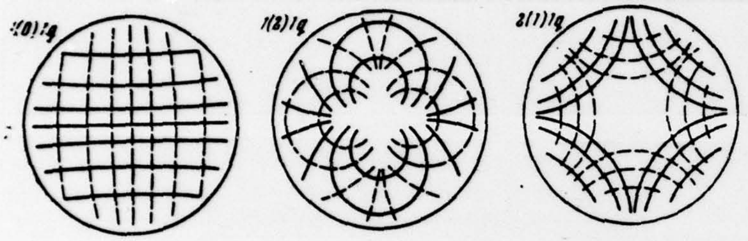

Fig. 3. Distribution of lines of force.

As follows from expressions (4) and (5), the distribution of lines of force for oscillations m(m+1)1q with m = 2, 3... is similar to distribution for oscillations 1(2)1q and differs from it only by azimuthal period (equal to π/m). In exactly the same way the distribution of lines of force for oscillations m(m-1)1q with m = 3, 4... differs from the distribution for oscillation 2(1)1q by azimuthal period, equal to π/m (taking into account the direction of lines of force in both cases the azimuthal period is equal to $2\pi/m$).

The discussed theory of natural oscillations holds true with s<<1, i.e., with

$$M=\sqrt{\frac{2k}{l}}a=\frac{2ka}{\sqrt{\pi q}}\gg 1. \quad (17)$$

This means that with q ~ 1 there should be $ka\gg 1, a\gg l$; with $q\gg 1$ there can also be $l\gg a$. Thus, on the theory developed above on the ratio of the diameter of disks to the distance between them there are not imposed any limitations. With $q\to\infty$ parameters $\beta_H''\approx\beta_E''\approx\beta'$ approximately coincide with β, and our formulas change into formulas of work [1].

§ 3. EXCITATION OF PLANE WAVE

Let us examine the excitation of the open resonator of a plane wave, hitting the resonator along axis z. The disks of the resonator are assumed slightly transparent; we will characterize them by the reflection factor R and the transmission coefficient T, where $R\approx 1$, $|T|\ll 1$, which is necessary for the existence of high-quality oscillations. In this case as before we can use expressions (4), (5), (11) and (12) for writing the natural oscillations, however now

$$v_q l=\pi\left(\frac{q}{2}+\rho\right), \quad (18)$$

where parameter ρ is connected with the complex reflection factor R

by relation

$$\rho = \frac{i}{2\pi} \ln R. \tag{19}$$

The wave falling on the top disk will soak through inside the resonator and on the bottom side of the top disk excite electrical and magnetic currents with surface density

$$j_x^e = \frac{c}{4\pi} TE_0 e^{-ikl}, \; j_y^m = -\frac{c}{4\pi} TE_0 e^{-ikl}, \tag{20}$$

where E_0 - amplitude of incident wave

$$E_x = -H_y = E_0 e^{-ikz}. \tag{21}$$

Thus, the posed problem is reduced to the calculation of excitation of disk resonator by currents (20). By solving it in the first approximation, we will assume in expressions (4) and (5) D = 0 for oscillations m(m-1)nq and C = 0 for oscillations m(m+1)nq.

With the assumptions made, we can obviously use the theory of excitation of ordinary volume resonators ([3], § 101) and consider that amplitudes A_s of electrical and B_s of magnetic field of s-th oscillation are determined by formulas

$$\left.\begin{aligned} A_s &= -\frac{i}{\omega^2-\omega_s^2}\frac{1}{N_s}\int(\omega \mathbf{j}^e \mathbf{E}_s - \omega_s \mathbf{j}^m \mathbf{H}_s)dS, \\ B_s &= -\frac{i}{\omega^2-\omega_s^2}\frac{1}{N_s}\int(\omega_s \mathbf{j}^e \mathbf{E}_s - \omega \mathbf{j}^m \mathbf{H}_s)dS, \end{aligned}\right\} \tag{22}$$

where ω - frequency of excitation, subscript s replaces four of our

subscripts, characterizing a specific type of oscillations, integration is performed with respect to the bottom side of the top disk $z=l$, N_s - standard of natural oscillation

$$N_s = \frac{1}{4\pi i}\int_V E_s^2 dV = -\frac{1}{4\pi}\int_V H_s^2 dV, \tag{23}$$

V - volume of resonator $(-l<z<l,\ 0<r<a)$. Let us note that in our case it is necessary to consider natural frequencies complex $(\omega_s = \omega_s' - i\omega_s'')$ and to take into account in them the presence of losses, connected with radiation to the sides and the transparency of disks, at the same time the distribution of fields can be taken without taking into account losses.

By substituting expressions (20), (4), (5) in (22), (23), we arrive at the conclusion that the plane wave excites only oscillations 1(0)nq. In the first approximation inside the resonator the electromagnetic field will have components

$$\left.\begin{aligned} E_x &= \sum_{n,q} A_{nq} J_0\left(\frac{\nu_{0n} r}{a}\right)[e^{iv_q z} - (-1)^q e^{-iv_q z}], \\ H_y &= \sum_{n,q} B_{nq} J_0\left(\frac{\nu_{0n} r}{a}\right)[e^{iv_q z} + (-1)^q e^{-iv_q z}] \end{aligned}\right\} \tag{24}$$

and components E_z and H_z, which we do not write out $(E_y = H_x = 0)$. Coefficients A_{nq} and B_{nq} are determined by formulas

$$\left.\begin{aligned} A_{nq} &= e^{-i(k-v_q)l}\,\frac{iTE_0}{kl\nu_{0n}J_1(\nu_{0n})}\,\frac{\omega_{nq}\omega}{\omega^2-\omega_{nq}^2}, \\ B_{nq} &= e^{-i(k-v_q)l}\,\frac{iTE_0}{kl\nu_{0n}J_1(\nu_{0n})}\,\frac{\omega^2}{\omega^2-\omega_{nq}^2}, \end{aligned}\right\} \tag{25}$$

where

$$k_{nq}l = \frac{\omega_{nq}}{c} l = \pi\left(\frac{q}{2} + p + \rho\right). \tag{26}$$

With $\omega = \omega'_{nq}$, in particular, from formula (25) we obtain

$$A_{nq} = B_{nq} = \frac{2iTE_0}{\pi q \nu_{0n} J_1(\nu_{0n})} Q, \tag{27}$$

where the quality factor of the resonator Q is determined by expression

$$Q = \frac{\omega'}{2\omega''} = \frac{q}{4(p'' + \rho'')}, \tag{28}$$

where

$$p = \frac{\nu_{0n}^2}{\pi (M + \beta' + i\beta'')^2} = p' - ip'' \text{ и } \rho = \rho' - i\rho''. \tag{29}$$

The resonance values of (27) with $\rho'' < p''$, i.e., with prevalence of diffraction losses, are inversely proportional to $\nu_{0n}^{5/2}$ and $q^{1/2}$, i.e., with increase of subscripts n and q decrease rather rapidly. With prevalence of losses on disks $(\rho'' > p'')$ the resonance losses (27) are inversely proportional to $\nu_{0n}^{1/2}$ and do not depend on q.

CONCLUSION

Recently there appeared experimental works, in which open

resonators of the examined type are applied. So, in [8] there were used resonators, formed by wire lattices (otherwise, anisotropy of these systems leads to additional rarefaction of the spectrum; in such a system there can be only oscillations 1(0)nq, polarized along the wires of the lattice). Under the effect of these works there appeared the problem, solved below.

Let us note that the similar problem for open resonator, formed by rectangular mirrors, turns out to be simpler, it is solved in book [4].

I deeply thank L. A. Vaynshteyn for posing the problem and for guidance.

APPENDIX

Curves of Fig. 2 were calculated by us by formulas

$$
\left.
\begin{aligned}
&\beta' = -\sqrt{\frac{q}{\pi}}\left[\ln\frac{\gamma q}{4}+\sum_{m=1}^{\infty}\left(\frac{1}{\sqrt{m(m+q)}}-\frac{1}{m}\right)\right], \quad \gamma = 1{,}781,\\
&\beta''_H = \frac{1}{\sqrt{\pi q}}+\sqrt{\frac{q}{\pi}}\left(\frac{\pi}{2}-2\sum_{m=1}^{\frac{q-1}{2}}\frac{1}{\sqrt{q^2-(2m-1)^2}}\right), \quad q=1,3,\ldots,\\
&\beta''_H = \sqrt{\frac{q}{\pi}}\left(\frac{\pi}{2}-2\sum_{m=1}^{\frac{q-2}{2}}\frac{1}{\sqrt{q^2-(2m)^2}}\right), \quad q=2,4,\ldots.\\
&\beta''_E = \beta''_H-\frac{2}{\sqrt{\pi q}},
\end{aligned}
\right\} \quad (30)
$$

which were obtained from the corresponding expressions of book [2]. In this case

$$
\lim_{q\to\infty}\beta' = -\frac{1}{\sqrt{\pi}}\lim_{q\to\infty}\left\{\sqrt{q}\ln\frac{\gamma q}{4}+\sqrt{q}\lim_{t\to\infty}\left[\sum_{m=1}^{t}\left(\frac{1}{\sqrt{m(m+q)}}-\frac{1}{m}\right)+\right.\right.
$$
$$
\left.\left.+\int_t^{\infty}\left(\frac{1}{\sqrt{x^2+qx}}-\frac{1}{x}\right)dx\right]\right\} = -\frac{1}{\sqrt{\pi}}\lim_{t\to\infty}\left\{\sum_{m=1}^{t}\frac{1}{\sqrt{m}}-\right.
$$
$$
\left.-\lim_{q\to\infty}\left[\sqrt{q}\ln\left(1+\frac{2}{q}t+\frac{2}{q}\sqrt{t^2+qt}\right)\right]\right\} = \beta = 0{,}824,
$$

since (see, for example, [5], p. 71)

$$
\lim_{t\to\infty}\left(\sum_{m=1}^{t}\frac{1}{\sqrt{m}}-2\sqrt{t}\right) = \zeta(1/2) = -1{,}460,
$$

where $\zeta(x)$ - zeta-function of Riemann. Similarly it is possible to show that

$$
\lim_{q\to\infty}\beta''_H = \lim_{q\to\infty}\beta''_E = 0{,}824.
$$

As is known, with decrease of the distance between plates of flat waveguide the beam pattern of radiation is weakened from its open end, therefore with q ~ 1 flanges can become an essential effect. However, the calculations, performed on the basis of the

variation method [6], show that with q = 1 the account of flanges leads to such a decrease of values $\beta'_{E,H}$ and $\beta''_{E,H}$:

$$\Delta\beta'_E = 0{,}125,\quad \Delta\beta''_E = 0{,}175,\quad \Delta\beta'_H = 0{,}065,\quad \Delta\beta''_H = 0{,}070$$

and with q = 3

$$\Delta\beta'_E = 0{,}014,\quad \Delta\beta''_E = 0{,}140,\quad \Delta\beta'_H = 0{,}055,\quad \Delta\beta''_H = 0{,}068.$$

More precise calculation of these corrections can be obtained by iterations during the solution of infinite system of equations, obtained in [7] for waveguide with flanges. It is interesting to note that, being limited in this system by diagonal terms, we once more arrive at results, obtained in [6] by the variation method.

BIBLIOGRAPHY

1. Л. А. Вайнштейн. ЖЭТФ, 44, № 3, 1050, 1963.
2. Л. А. Вайнштейн. Дифракция электромагнитных и звуковых волн на открытом конце волновода. М., Изд-во «Сов. радио», 1953.
3. Л. А. Вайнштейн. Электромагнитные волны. М., Изд-во «Сов. радио», 1957.
4. Л. А. Вайнштейн. Открытые резонаторы и открытые волноводы. М., Изд-во «Сов. радио», 1966, стр. 57.
5. Э. Т. Уиттекер, Дж. Н. Ватсон. Курс современного анализа, ч. 2. Перев. с англ. ИЛ, 1963.
6. Л. Левин. Современная теория волноводов. Перев. с англ. ИЛ, 1954.
7. H. M. Nussenzweig. Solution of a diffraction problem. Phil. Trans. Roy. Soc. London, Series A. Math. Phys. Sci., 252, 1—51, 1959.
8. Е. А. Виноградов, Е. М. Дианов, Н. А. Ирисова. Письма в ЖЭТФ, 2, № 7, 323—326, 1965.

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